PROCEEDINGS

OF

THE FIRST

NATIONAL CONFERENCE

ON

FITNESS-FOR-SERVICE IN SHIPBUILDING

Dr. Leslie W. Sandor
Editor-in-Chief
and

Conference Organizer

Venue: National Bureau of Standards
Building 2
Boulder, Colorado 80303

Time: October 23-24, 1980

Sponsored
by
SP-7 Panel
Ship Production Committee
Society of Naval Architects and Marine Engineers
USA

January 1, 1981

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Dear Speakers and Delegates:

On behalf of the SNAME Ship Production Committee SP-7 Panel, I wish to express my heart-felt thank you for your excellent contribution and fine efforts to our 1st conference on "Fitness-for-Service in Shipbuilding", held in Boulder, Colorado at NBS on October 23-24, 1980.

With kind regards!

Yours sincerely,

Les Sandor

L. W. Sandor
Manager for National
Shipbuilding Research Program

LWS:bd

August 29, 1980

This is a preliminary announcement to inform you that a conference on

"FITNESS-FOR-SERVICE IN SHIPBUILDING"

will be held at

National Bureau of Standards
Boulder, Colorado
October 23-24, 1980

The purpose of the conference is to generate U. S. Shipbuilding Industry Policy on New Weld Acceptance Standards.

The SP-7 Panel members are asked to attend. Special invitations are also extended to Q.A., Q.C. and N.D.T. personnel to participate in this important workshop. It is vital that experts of key sectors of the American Shipbuilding Community contribute to the making and an agreement of The Policy. An intent is that the attendees represent a reasonable balance between shipbuilders composed of welding and NDT experts, and U. S. code making bodies.

The consensus of the U. S. shipbuilding industry and indeed that of the international welding fraternity has for quite some time been one of clear expression of the need to minimize unnecessary weld repair, notably in the realms of porosity and slag inclusions. However there has not been a paved mechanism to bring that burning desire for New Weld Acceptance Standards to fruition.

The format of the conference programs is being so set up as to provide on the first day room for brief presentations on Fitness-for-Service, Fracture Mechanics, Appropriate N.D.T. Methods, Fatigue, Statistical Approach, Quality Control Systems Loop, Views of Code Making Bodies, Origin, Nature and Metallurgical Significance of Weld Discontinuities, The Real Meaning of Weld Repair. On the second day the workshop will be transformed into an open forum for presentations and frank discussions of ideas, suggestions, directions and recommendations of value to the end product of the conference: THE POLICY ON NEW WELD ACCEPTANCE STANDARDS FOR THE U.S. SHIPBUILDING INDUSTRY.

The Conference may wish to propose a submittal of THE POLICY to the Technical Committee of A.B.S. and to the appropriate authority of the U.S. Coast Guard for their respective response. The S.N.A.M.E. Ship Production Committee will be informed of THE POLICY. Any subsequent plan of action(s) will be contingent upon the nature of the response by A.B.S. and Coast Guard.

All of you planning to attend the conference are urged to come as well prepared as possible but with an open mind.

See you at Boulder!

Sincerely,

Les

Dr. L. W. Sandor
Manager for National Shipbuilding
Research Program

LWS:jrb

P.S. AGENDA for the conference will follow shortly.

Sun Ship

1st

CONFERENCE

on

"FITNESS-FOR-SERVICE IN SHIPBUILDING"

Purpose: To generate U. S. Shipbuilding Industry Policy on New Weld Acceptance Standards.

Venue: National Bureau of Standards
Boulder, Colorado 80303

Building 2

Time: October 23-24, 1980

AGENDA

October 23, 1980

Morning Session: 8:30 a.m.
Moderator: Mr. R. R. Hardison
Newport News Shipbuilding

1. Dr. L. W. Sandor, Sun Ship, Inc. — "The Meaning of Weld Discontinuities in Shipbuilding".

2. Dr. H. I. McHenry, National Bureau of Standards — "The Development of Fitness-for-Service Standards for Shipbuilding".

Coffee Break- (l5')

3. Dr. M. G. Dawes, The Welding institute/NBS — 'lFitness-for-Service Criteria Based on Fracture Mechanics--Current Approaches and Experience".

4. Mr. S. M. Fisher, Virginia Polytechnic Institute and State University — "The Structural Integrity of Copper/Nickel-Steel Welds".

Luncheon (12:00-1:30 p.m.)

Afternoon Session: 1:30 p.m.
Moderator: Mr. Jon Fallick
Sun Ship, Inc.

1. Professor C. Lundin, University of Tennessee — "Origin, Nature and Metallurgical Significance of Weld Discontinuities".

2. Dr. M. B. Kasen, National Bureau of Standards — "Radiographic Evaluation of the Significance of Weld Defects".

Coffee Break (15')

3. Dr. C. M. Fortunko, National Bureau of Standards — "Ultrasonic Detection and Sizing of. Weld Defects".

4. Mr. B. Alia, American Bureau of Shipping — "Comments on ABS Nondestructive ln-spection of Hull Welds".

5. Cdr. J. C. Card, U. S. Coast Guard — "Acceptance of Industry Standards - The Coast Guard Approach".

October 24, 1980

Morning Session: 9:00 a.m.

Moderator : Dr. Leslie W. Sandor, Sun Ship, Inc.

(A) OPEN SESSION MEETING

Overview, Analysis of first day Presentations

Suggestions for Policy Formulations

Coffee Break (15')

(B) POLICY PLANNING SESSION

Establishment of Task Groups, each made up of mix of experts of the conference attendees for the purpose of drafting The Policy on New Weld Acceptance Standards.

General Assembly of all Task Groups to write THE POLICY.

Proposals for submission of THE POLICY
- (1) for response from
  - (1.1) Technical Committee of A.B.S.
  - (1.2) Appropriate Authority of Coast Guard
- (2) for informing
  - (2.1) SNAME Ship Production Committee

Luncheon (12:00-1:30 p.m.)

Afternoon Session: 1:30 p.m.
Organizer: Dr. Harry 1. McHenry
National Bureau of Standards

1. Tour of NBS Facilities

2:30 p.m. Adjournment

NOTE :

Speakers are asked to observe the rule of 30 minutes for talk followed by 15 minutes for question-answer period.
Moderators are urged to enforce the rule in order to meet our busy schedule.

SPEAKERS' SYNOPSES

1st Day of the Conference

"THE MEANING OF WELD DISCONTINUITIES
IN
SHIPBUILDING"

b Y

Dr. L. W. Sander
Manager for National Shipbuilding
Research Program
Sun Ship, Inc., Chester, Pa 19013

SYNOPSIS

The basic thrust of understanding the engineering meaning of weld discontinuities' is to decrease the cost of welded structures through avoiding unnecessary repairs of harmless weld discontinuities.

Phase I of the "Weld Defect Tolerance Study" project was directed at commercial ships involving the "mild steel" type material.

When failures in such ships occur - usually during the first 2-4 years in service after launch - the predominant failure mode was found to be fatigue caused mostly by poor design details and undesirable fit up or joint misalignments. Weld discontinuities as an exclusive cause of in-service ship "failures rank extremely low among the many causes reported in both the international literature and private correspondence. Of all known failure causes, the ratio of non-weld related to those which were weld defects related is 6:1. Weld discontinuities may be categorized in decreasing order of importance as follows:

1. Crack or crack-like
2. Geometric
3. LOF/LOP
4. Slag
5. Porosity

Of these discontinuities, the literature regards porosity and slag inclusions as the least detrimental to the structure. There are many well-known case histories published or otherwise documented, which show clearly that weld repair often turned out to be more deleterious in terms of weldment survivability due to a number of undesireable phenomena associated with such repairs than had the original harmless defect been left untouched in the welded construction. Weld repair should, therefore, not be looked upon as an automatic, concomitant improvement

A statistical analysis of data and general quality control information obtained in a survey taken in key U.S. shipyards unequivocally points to slag inclusions and porosity as the two most frequently repaired discontinuities. Another rather revealing observation was that a change - wherever possible - from SMAW to "wire welding" processes would bring about a two-fold improvement:

1. a decrease in the occurrance of slag inclusions and,
2. an increase in weld productivity.

The costs of weld repair were estimated to have ranged from $0.6 million to $1.0 million per ship. A paradox of all this is that slag and porosity are the two most innocuous discontinuities considered in the world literature. Experts believe that the bulk of this weld repair activity, especially when it comes to small size slag and porosity, is superfluous. This would then suggest that existing weld acceptance standards ought to be reviewed. Furthermore, as a compliment to optimizing existing workmanship-type standards, the introduction as an option - of a more rational weld acceptance standards based on engineering critical assessment - such as fracture mechanics - might prove to be judicious.

Since failures in sea-going ships may be induced by several and different causes, the "Quality Control Systems Loop" (QCSL) proposes to be a cost effective tool for establishing a definite cause-and-effect relationship: hence, the elimination of repetitive errors. For instance, today it is not known how the inspected joints or welds irrespective of the presence or absence of discontinuities fair in service.

In the present system of quality assurance, the only time information is supplied from the field is if and when there is a failure. The present “formal inspection system"lends itself to defect accumulation giving rise to excessive repair costs. While QCSL involving full participation not only during fabrication but in service of the ship as well becomes like an early warning system. QCSL is illustrated in Fig. 1.

To derive maximum cost benefits and to achieve the highest level of confidence in the improved weld acceptance standards, all approaches taken to that end require a methodical development and well-planned coordination. Such a multipronged master plan is destined to minimize “guess work” and raise the floor of overall quality in the end product: which must be a commendable act for every one concerned. lt is undoubtful that after a due process of mutual assimilation of the various approaches, and from the working knowledge gained through experience with them, there will emerge a real good weld acceptance standards.

Phase II of the program was prompted by the U.S. shipbuilding industry's response to the results of the Phase I Study.

Phase II involves a statistical examination of available quality control data pertaining to naval surface ships built of the “mild steel” type material. Naval ships constructed from high strength steels is excluded from this study.

This first conference on “Fitness-for-Service in Shipbuilding” sprouted from the weld defect tolerance project.

A recommendation promulgated in the Phase I report to organize an international conference on fitness-for-service/purpose was also readily accepted by the British Welding Institute and is scheduled for November 17-19, 1981, London, England.

Offers of co-sponsorship have been received from AWS, WRC, NBS(Boulder).

It was felt, among others, that there was a profound need to bring into focus in a world forum the practicality of fracture mechanics principles and the experience of their adoptation process into standards in specific industries.

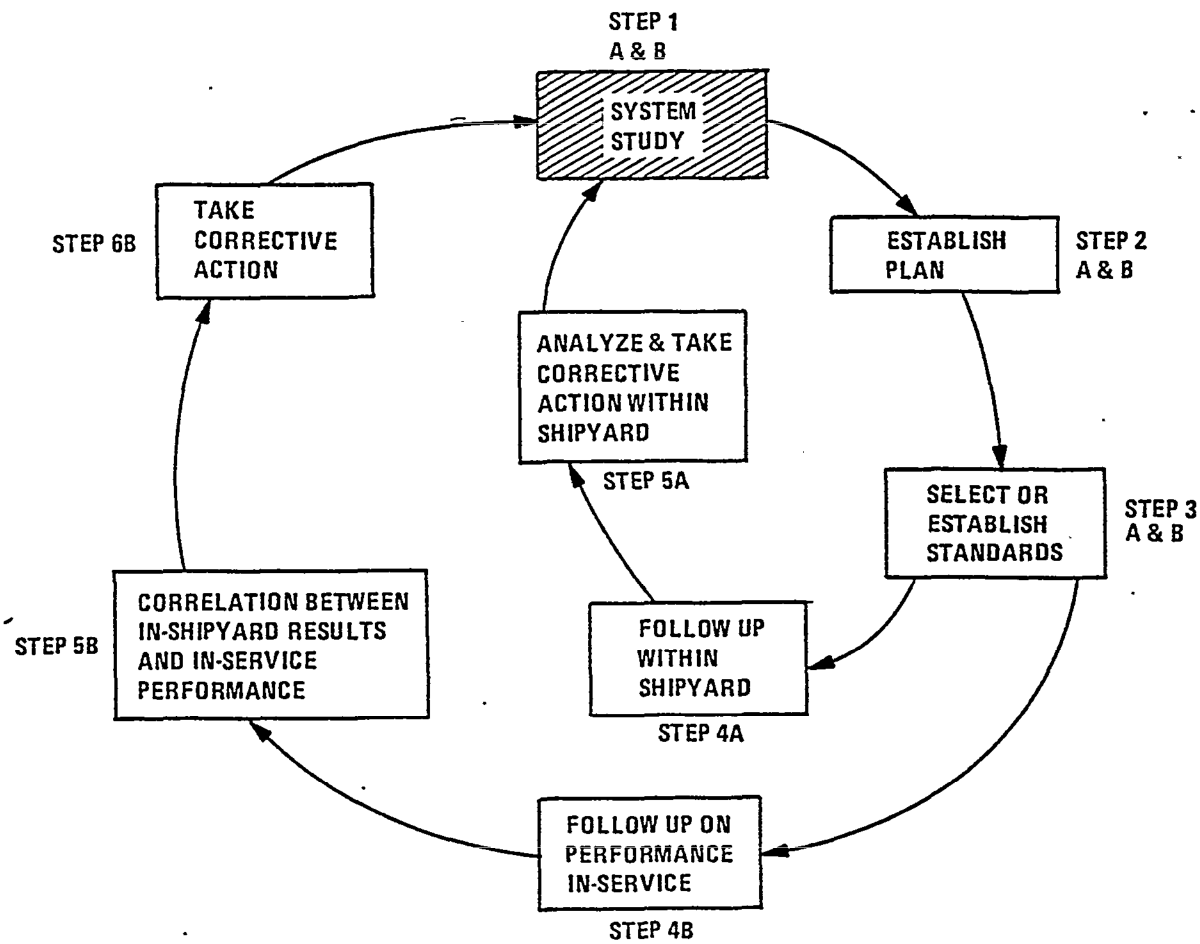


Fig. 1 Schematic Diagram of QCSL

Loop "A": in-shipyard scenario for short-range benefits

Loop "B": in-shipyard and in-service scenario for longer-range benefits and establishment of cause-and-effect relationships.

Development of Fitness-for-Service Standards for Shipbuilding

Harry I. McHenry
National Bureau of Standards
Fracture and Deformation Division
Boulder, CO 80303

ABSTRACT

Weld quality standards based on fitness-for-service concepts are derived on the basis of an analytical relationship between ship opersting stress levels, fracture toughness of ship hull weldments, and flaw sizes in the welds. Such a relationship has been developed by the Welding Institute and incorporated into a British Standards Institution publication entitled: Rules for Derivation of Acceptance Limits for Defects in Fusion Welded Joints. The British approach has been used as the basis for weld quality requirements for numerous types of engineering structures including ships, offshore structures and pipelines. It is the theme of this presentation that these rules should be applied to the development of weld quality standards for ship hull weldments. Implementation of these standards would require significant parallel developments, specifically flaw sizing by ultrasonic testing methods and a fracture toughness data base for ship steel weldments.

The development of weld quality standards would require a fracture mechanics analysis in accordance with the British procedures. The validity of the proposed standards would be assessed by an experimental verification program and by a survey of ship operating experience. Particular emphasis is required in the areas of fatigue assessment and definition of operating stress levels. A trial standard would be evaluated by cooperating shipyards and by the ABS. The trial standard would

be revised to incorporate shipyard experience and the results of the parallel development programs in ultrasonic testing and fracture toughness testing.

Implementation of the fitness-for-service standards would require significant developments in flaw sizing by ultrasonic testing. A program is proposed to develop a long wavelength ultrasonic technique that uses horizontal shear waves excited by electromagnetic acoustic transducers (EMAT) described in the presentation by C. M. Fortunko. The development program would include transducer development and calibration" by NBS, followed by shipyard trials of a prototype system. Successful shipyard experience would lead to contracts with industry to develop mechanical handling devices and an improved, ruggedized prototype, and finally, a commercial system for shipyard implementation.

Application of the fitness-for-service standards would require a fracture toughness data base on representative ship steel weldments. It is proposed that the interested shipyards be responsible for the development of the data base. NBS would assist the shipyards in the development of their testing capabilities and in the evaluation of the data. Data are needed on the ABS steels, a variety of weld metal types and on weldments produced by the various welding processes used in ship construction.

In summary, the development of weld quality standards based on fitness-for-service will require a concerted effort by the shipbuilding industry. A five-year program is anticipated with participation by shipyards, MarAd, ABS, NBS and industrial contractors.

1st Conference on Fitness-for-Service in Shipbuilding

National Bureau of Standards
Boulder, Colorado 80303
October 23-24, 1980

Paper 3: "Fitness-for-Service Criteria Based on Fracture Mechanics - Current Approaches and Experience"
ByM. G. Dawes, The Welding Institute/NBS

Synopsis

For ships and other welded structures to be fit-for-service they must have adequate resistance to such relevant failure modes as fatigue, brittle fracture, corrosion, erosion, corrosion fatigue, stress corrosion, leakage in containment vessels, yielding or ductile tearing due to overloading of remaining cross-sections, buckling and creep. Of these, fatigue failure and brittle failure are considered to be the most important, since these are generally the most common and potentially catastrophic, respectively. In the context of a ship, "failure" by fatigue or brittle fracture may be defined as the occurrence of an extent of cracking that has either potential for, or actually results in one or a combination of the following: sinking, capsizing, significant 1eakage into and/or out of the hull, malfunction of shipboard equipment, and any other restriction on normal service operation.

The majority of service fatigue failures can be avoided by careful attention to the design details. This is particularly true in the case of welded joints, in which metallurgical factors have a relatively minor significance. For a more complete fatigue assessment of welded joints, however, it is necessary to consider both the detail design and the significance of weld defects. This is also true of assessments of

resistance to brittle fracture, except in this case the resistance to brittle fracture is also heavily dependent upon metallurgical factors. From the viewpoint of avoiding fatigue failures in welded joints, many design standards and codes-of-practice categorize such weld defects as slag inclusions and porosity as "non-planar" defects, and cracks and crack-like defects such as lack-of-penetration and lack-of-fusion as "planar" defects. In these instances, design against fatigue failure is generally based on lower bound log stress range versus log stress cycles relationships (S-N curves) for different geometrical details and severities of non-planar defects. Unfortunately, these simple approaches are rarely considered adequate in the case of planar weld defects, which are both more complex and more easily handled using a fracture mechanics approach.

The basic principles and most common parameters of fracture mechanics are outlined in this paper, and it is also indicated how these may be applied to assessments of the significance of weld flaws in relation to failure by both fatigue and brittle fracture. All the fracture mechanics parameters are covered by either full national standards or advanced drafts for such standards, e.g.

ASTM E647 test for constant-load-amplitude fatigue crack growth rates

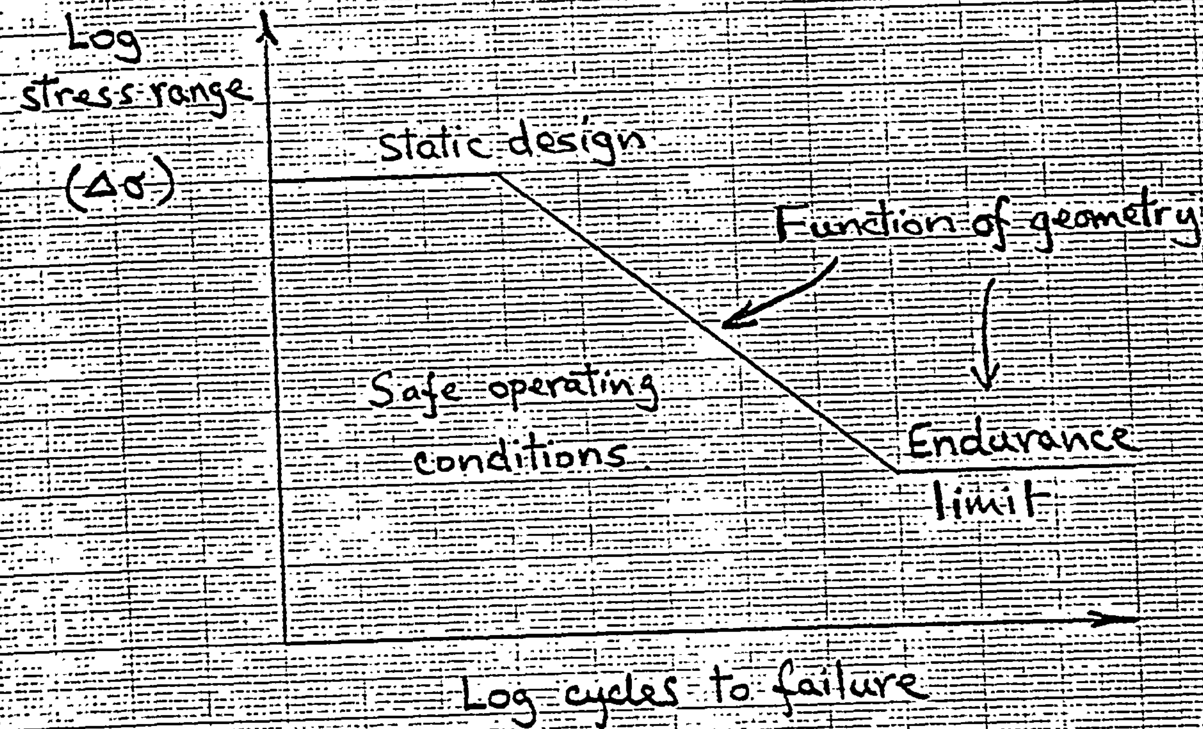
ASTM E399 and BS 5447 tests for K_{IC}

ASTM draft and BS 5762 tests for C(T)OD testing.

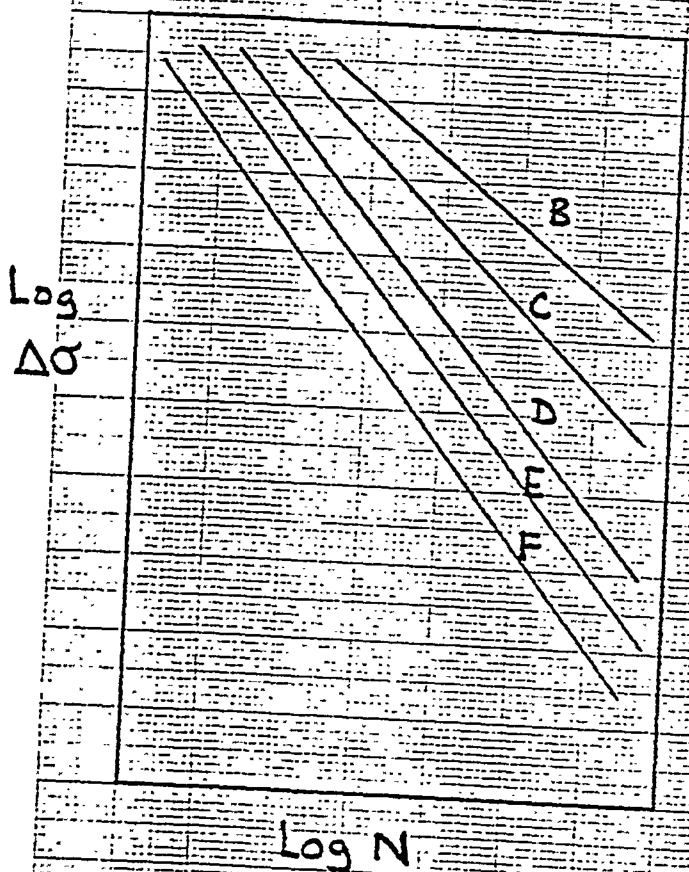
The early development of a K_{IC} test standard resulted in the inclusion of fracture mechanics assessments in the ASME Boiler and Pressure Vessel Code for nuclear vessets, e.g.

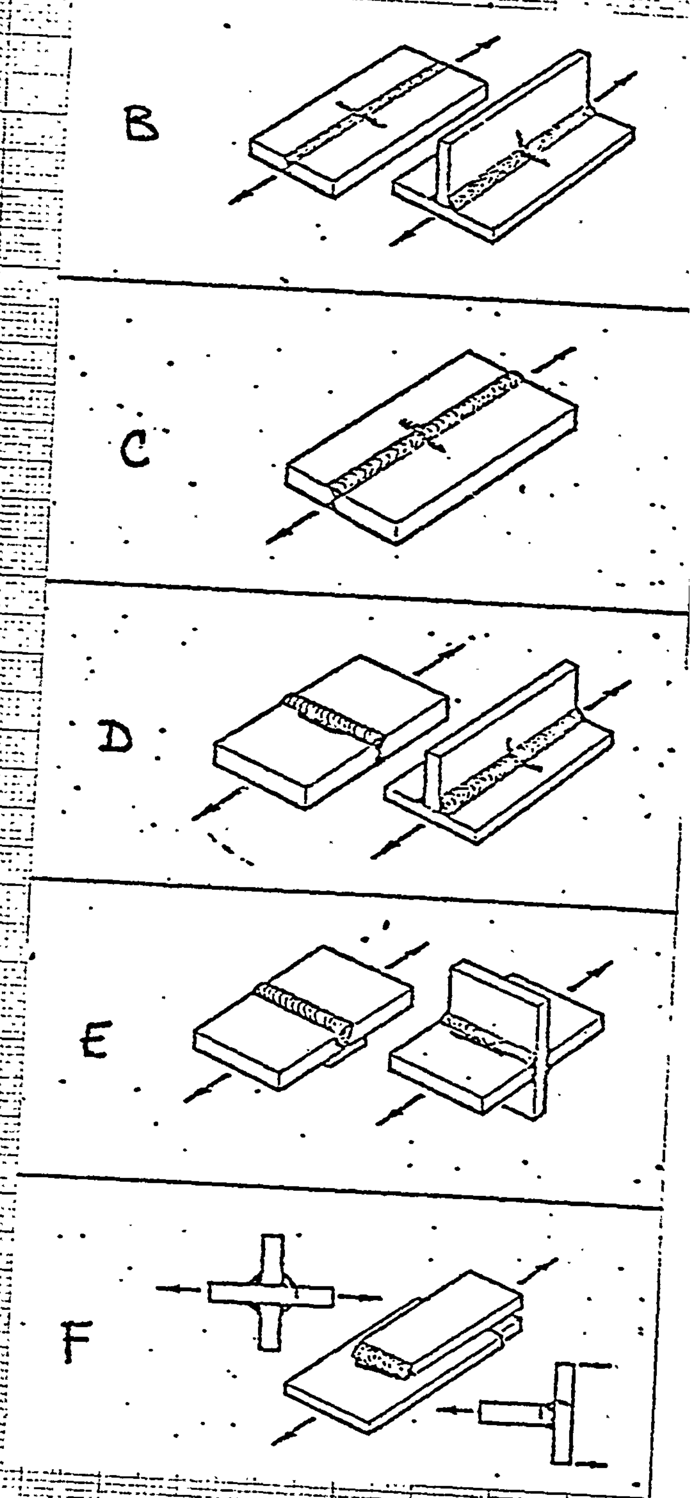
ASME Section III, Appendix G and ASME Section XI, Appendix I. These design standards may be considered to have set a precedent for many other sections of the engineering industries. Around the world many large companies in the oil, gas, chemical and power generation industries are now specifying codes of practice based on fracture mechanics assessments of fitness-for-service. In Britain, the British Standards for pressure vessels, bridges, storage tanks and fixed off-shore structures allow the use of fracture mechanics assessments by agreement of the parties involved. Advice on how to apply fracture mechanics to a wide range of different welded structures is given in a recent British Standards Institution-published document, PD 6493, which is entitled “Guidance on some methods for the derivation of acceptance levels for defects in fusion welded joints”.

It may be noted that BSI Document PD 6493 includes an assessment of fitness-for-service based on the C(T)OD approach; which was originally developed at The Welding Institute. In this context it is of interest to mention that ASTM Special Technical Publication, STP-668, summarizes a wide range of experience and applications of the C(T)OD approach in the years approximately 1972-77. In one application involving off-shore structures it was estimated that a fitness-for-service assessment resulted in a saving of approximately $120 million. The final assessment of the Aleyaska pipeline indicated that many millions of dollars had been spent in unnecessary weld repairs. Unfortunately, most of the Aleyaska pipeline weld repairs had been completed by the time the relevant authorities had been convinced about the relevance and reliability of a fracture mechanics approach. One section which had not been repaired at this stage, however, involved crossing the Koyukuk River. The avoidance of repairs in this section of pipeline alone was estimated to have saved approximately $5 million. Finally, it is of interest to note that a 1973 survey of the British pressure vessel industry concluded that 80% of the weld repairs were unnecessary from a fitness-for-service viewpoint.


Log
stress range
(Δσ)
Static design
Function of geometry
Safe operating
conditions
Endurance
limit
Log cycles to failure

WELDED DETAILS



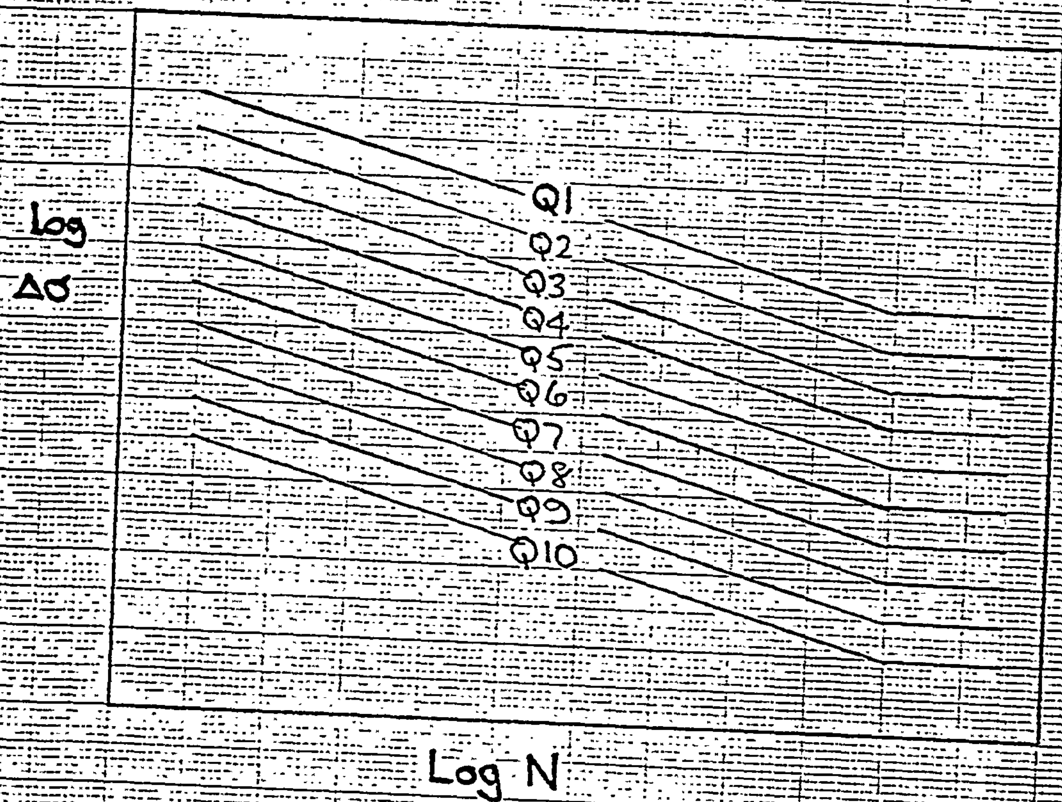


DEFECTS IN WELDS

TWO CATEGORIES ARE USUALLY CONSIDERED:

NON-PLANAR	PLANAR
POROSITY	CRACKS
SLAG INCLUSIONS	LACK OF PENETRATION
	LACK OF FUSION

NON-PLANAR DEFECTS

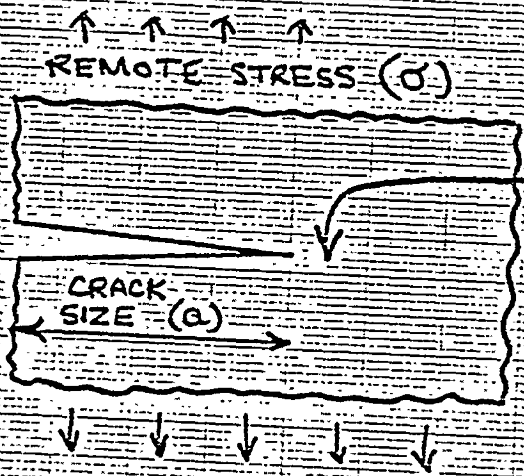


QUALITY CATEGORY (AS-WELDED)	SLAG INCLUSIONS	POROSITY	
	LENGTH, mm	% AREA ON RADIOGRAPH	INDIVIDUAL PORE
Q1	2·5	3	6 mm OR 1/4 PLATE THICK IF LESS THAN 6 mm
Q2	4	3	
Q3	10	5	
Q4	35	5	
Q5	CONTINUOUS	5	
Q6–10	CONTINUOUS	5	

PLANAR DEFECTS

- USE FRACTURE MECHANICS FOR BOTH FATIGUE AND BRITTLE FRACTURE.

a) LINEAR ELASTIC FRACTURE MECHANICS (LEFM)



THE SEVERITY OF THE CRACK TIP ENVIRONMENT,

$$K = Y\sigma\sqrt{\pi a}$$

WHERE, $Y = f$(GEOMETRY)

FOR FATIGUE LOADING WE HAVE

$$\Delta K = Y . \Delta\sigma\sqrt{\pi a}$$

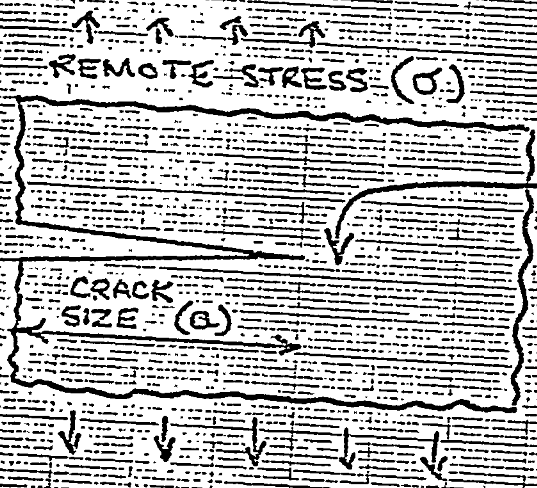
FOR A WIDE RANGE OF ΔK IT CAN BE SHOWN THAT

$$\frac{da}{dN} = C(\Delta K)^m$$

SUBSTITUTING FOR ΔK AND RE-ARRANGING GIVES

$$\int_{a_1}^{a_2} \frac{da}{(Y\sqrt{\pi a})^m} = C(\Delta\sigma)^m N$$

a) LEFM (CONTINUED)



THE SEVERITY OF THE CRACK TIP ENVIRONMENT,

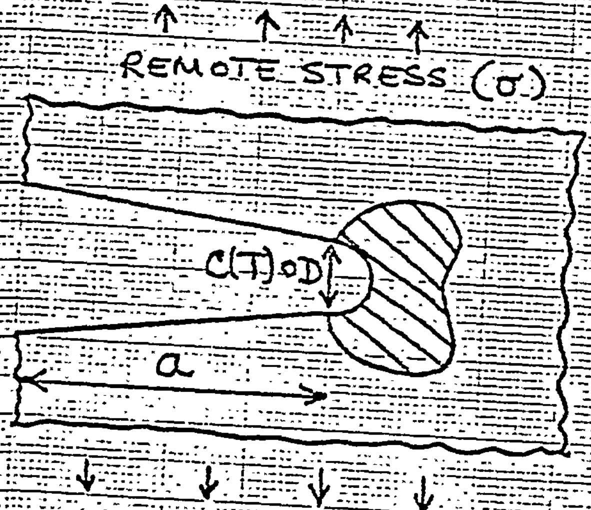
$$K = Y \sigma \sqrt{\pi a}$$

WHERE, $Y = f(\text{GEOMETRY})$

THE CRITICAL CONDITIONS FOR BRITTLE FRACTURE ARE GIVEN BY

$$K_{Ic} = \underbrace{\underset{\text{GEOM. FUNCT.}}{Y_T}\ \underset{\text{CRIT. STRESS}}{\sigma_{CT}}\ \underset{\text{CRIT. SIZE}}{\sqrt{\pi a_{CT}}}}_{\text{TEST PIECE}} = \underbrace{\underset{\text{GEOM. FUNCT.}}{Y_S}\ \underset{\text{CRIT. STRESS}}{\sigma_{CS}}\ \underset{\text{CRIT. SIZE}}{\sqrt{\pi a_{CS}}}}_{\text{STRUCTURE}}$$

b) ELASTIC-PLASTIC FRACTURE MECHANICS (EPFM)



THE CRACK TIP OPENING DISPLACEMENT (CTOD),

$$\delta = f(\text{GEOM}, \sigma, a, \sigma_Y)$$

SEE ASTM-STP-668, PAGE 610.

$$\bar{a}_{max} = \frac{\delta_c E \sigma_Y}{2\pi\sigma_1^2}, \text{ for } \frac{\sigma_1}{\sigma_Y} \leq 0.5$$

$$\bar{a}_{max} = \frac{\delta_c E}{2\pi(\sigma_1 - 0.25\,\sigma_Y)}, \text{ for } \frac{\sigma_1}{\sigma_Y} \geq 0.5$$

Where, $\bar{a}_{max}$ = Half length of a through thickness crack.

δ_c = Critical C(T)OD.

E = Young's modulus

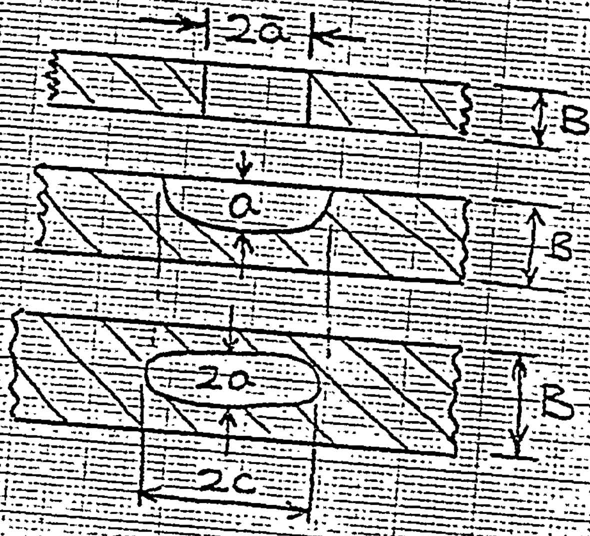
σ_1 = Effective stress
= $(SCF \times \sigma) + \sigma_R$

σ = Nominal or membrane stress

SCF = Stress or strain concentration factor.

σ_R = Residual stress

$$a_{max} = \bar{a}_{max} \times f\left(\frac{a}{B}, \frac{a}{2c}\right)$$



THE STRUCTURAL INTEGRITY OF COPPER-NICKEL! STEEL WELDS

The constant low **level** copper ion discharge during copper oxidation by sea water has long been known to repel marine organisms and in effect eliminate biofouling. In view of its current economic promise, a copper-nickel/steel cladding scheme is being developed for surface cladding ship hulls. Part of this development effort is an indepth study involving mechanical testing, engineering mechanics, as well as weld and weld defect characterization. The mechanical testing program includes testing and analysis of component configurations chosen to model various aspects of the cladding system. An engineering mechanics analysis will provide mathematical modeling of components tested in the mechanical test phase and prediction of the behavior of a prototype system under various loads. Weld and weld defect investigation includes metallurgical characterization of welds, prediction of crack propagation rates in various microstructures chosen to represent material conditions in the near weld zones, testing and analysis of typed weld defects and the subsequent establishment of a weld defect criterion.

S. M. Fisher, Engineering
Science and Mechanics
Virginia Polytechnic Institute
and State University
Balcksburg, Virginia 24061

AMERICAN BUREAU OF SHIPPING

9 December 1980

Summary of Presentation made at “Fitness-for-Service in Shipbuilding” Conference held at Boulder, Colorado, 23-24 October 1980

ABS Requirements for Nondestructive Testing of Hull Welds

The American Bureau of Shipping Rules provide for the following nondestructive testing methods:

- Visual
- Magnetic Particle
- Liquid Penetrant
- Radiographic
- Ultrasonic

In general, ABS Rules are useful to a wide variety of organizations including designers, shipbuilders, regulatory agencies, ship surveyuors and are applicable to new construction and repair under the variety of conditions encountered throughout the world. They are international in scope, intended to be sufficiently flexible to accommodate all situations, are representative of commercial quality and are primarily based on service performance.

Rules must be technically sound, formulated for prompt decisions, responsive to innovation and reflect latest developments. These objectives are achieved under the ABS procedures for Rule development, which involve utilization of Special Committees which are composed of eminent experts from Industry, Designers, Fabricators, Government, Specialists and Academia. Advisory review of Rules formulated by the ABS Technical Staff is provided by these committees as well as ABS Overseas Technical Committees and the Committee on Naval Architecture and the Committee on Engineering. Rules can only be established by the ABS Technical Committee, which is composed of top management experts representative of the major organizations related to the Marine Industry.

The chronology of the development of ABS radiographic standards which was subjected to normal Bureau committee review follows:

1963 Requirements were - “Inspection of welded joints in important locations is to be carried out preferably by an established radiographic technique, and the films are to be made available to the Surveyor.”

Feb. 1963 -- Nondestructive inspection questionnaire sent to various shipyards throughout world requesting information relative to their radiographic and ultrasonic inspection standards.

May 1965 - ABS Guide for Radiographic Inspection of Hull Welds issued on basis of findings of questionnaire.

Sept. 1971 - ABS issues Requirements for Radiographic Inspection of Hull Welds.

The following is the chronology of the development of ABS Ultrasonic Requirements:

May 1969 - ABS initiates development of requirements for ultrasonic inspection based on committee recommendations.

June 1972- Provisional Requirements for Ultrasonic Inspection of Hull Welds issued.

June 1975 - Formal Bureau Publication - ABS Rules for Nondestructive Inspection of Hull Welds issued which incorporates and updates Bureau radiographic and ultrasonic requirements for hull welds.

Currently ABS is engaged in the following two related projects which are supported by MARAD funding and SNAME SP-7 Welding Committee participation:

a) Guidance for evaluation of radiographic and ultrasonic indications of butt and seam welds between intersections and other welds where current ABS requirements do not apply.

b) Development of visual reference standards for weld surface appearance. When developed, these are expected to be duplicated as plastic mdoels, which would more clearly define various levels of weld surface imperfections. Upon agreement between the various parties concerned, these reference standards could serve as acceptance standards.

I. L. Stern
Assistant Cheif Surveyor

SUMMARY

Origin Nature and Significance

of Weld Discontinuities

Presentation October 23, 1980

Boulder Colorado - "Fitness For

Service in Shipbuilding Conference"

The macroscopic configuration of welded structures and secondly, the shape factors concerning welds (including fillet weld profiles, butt weld reinforcement and undercut) must be addressed before one . . considers micro-scale discontinuities. Without this consideration, the detailed assessment of micro-scale discontinuities is to no avail.

This presentation concerned itself with the evaluation of slag, porosity and lack of fusion pertaining to a potential for rapid growth or "pop-in" during fabrication or service. These discontinuities can be detected by various NDT Techniques, however, the fractographic evidence suggests a potential for enlargement to a crack-like discontinuity under tensile or bending strain or fatigue. If this condition exists, the discontinuities will be understated regarding size and acuity on initial discovery but may (in later service) present a greater potential for initiation of larger discontinuities.

The presentation showed that virtually all weld metal could display the brittle halo tendency around discontinuities (from E601O through E7018 to EI1018). The characteristic brittle region around discontinuities is absent under impact (high strain rate loading) thus giving credance to the postulate that the brittle nature of the fracture origination is related to the presence of hydrogen. The specific significance of the brittle "halos" or "pop~in"-regions is still being evaluated.

The program at The University of Tennessee is being sponsored by The PVRC of The Welding Research Council.

Carl Lundin
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RADIOGRAPHIC EVALUATION OF THE SIGNIFICANCE OF WELD DEFECTS

M. B. Kasen
Fracture and Deformation Division
National Bureau of Standards
Boulder, Colorado 80303

The primary questions that must be addressed in any fitness-for-purpose assessment of weld quality are: What flaws are significant in a given structure? At what dimensions do such flaws become critical, endangering the integrity of the structure? How good is the chosen NDE method for detecting and sizing such flaws?

Other than visual inspection, radiography is the most. commonly used method for examining the quality of a weld. While undoubtedly effective in judging the quality of a welders performance, it is necessary to question if radiography is equally effective in assessing the quality of welds on a fitness-for-purpose basis. Table I presents a breakdown of the types of weld flaws detected by radiography under field conditions. Although illustrated for a pipeline, the relative distribution of flaw types is probably typical of most manual welding operations. Most significant is the eight-to-one preponderance of blunt or three dimensional flaws. This will surprise no one familiar with radiography, because the ability of radiography to reveal a flaw is proportional to the difference in radiographic absorption of the flaw as compared to that of the surrounding metal. This difference is much higher for pores, inclusions and arc strikes than for sharp, two dimensional flaws such as cracks or lack of fusion. Furthermore, the detection of blunt flaws is independent of the orientation of the radiographic source relative to the weld, while the probability of detecting a sharp flaw is highly orientation dependent. It is easily demonstrated that a through crack along the fusion line of a manual weldment made with the usual 60° included angle joint preparation has a high probability of being missed by the interpreter under the best of radiographic conditions. It can therefore be concluded that the series of welds surveyed on Table I contain a much higher percentage of sharp, cracklike flaws than was actually observed.

This creates two problems. The most important is that many cracklike flaws, which have the highest probability of initiating weldment failure, go undetected. The second is that a substantial amount of money is spent to repair blunt flaws which may have a very low probability of initiating failure.

The fitness-for-purpose approach to assessing flaw significance in a given structure has been described in other papers in this series. One of the initial applications of this approach was to weldments of the Alyeska oil pipeline. Here it was necessary to assume that all flaws detected by radiography were significant as crack initiators and that those exceeding existing workmanship criteria required dimensioning and assessing by fracture mechanics criteria. This approach was nonconservative in assuming that the radiographs were revealing all the significant flaws and very likely over conservative in having to assume that blunt flaws were the equivalent of sharp flaws of equal dimension. This reflected the difficulty of assessing stress concentrations for blunt flaws. Furthermore, difficulty in assessing the through-wall dimensions of blunt flaws from the radiographs necessitated the assumption that such flaws were twice the estimated size.

The current fracture mechanics approach attempts to provide the basis for a more realistic method. It is assumed that radiography will very likely remain the primary NDE technique, but it also assumes that other techniques such as ultrasonics will provide a backup method for flaw sizing and may eventually supplant radiography as the primary inspection method. The current approach also continues to assume that two-dimensional, planar flaws are significant in all structures, requiring dimensioning and analysis by analytical fracture mechanics techniques. But the assumption is also made that blunt flaws may be innocuous in some structures, depending on the stresses and toughness of the weld metal, allowing permissible flaw content to be established on the basis of technical engineering judgment rather than by techniques requiring precise dimensioning. The advantage of this approach is significant cost saving if repair of noncritical flaws can be minimized and a significant increase in structural integrity by emphasizing the detection of potentially dangerous flaws.

The approach to the blunt flaw portion of this program has been reviewed in the literature.[1] In brief, It is assumed that flaws which can be shown to have a low probability of initiating cracks in welds subjected to stress regimes far more severe than those in service can be rationally judged to be innocuous under service conditions. The specific approach has been modelled after similar research by the British Welding Institute in a study of flaw significance in welded pressure vessels.[2] Weldments representing the parent materials, welding processes, procedures and consumables used in the actual structure and containing much higher levels of porosity, slag and arc strikes than would rationally be permitted under field conditions, are subjected to fully-reversed, low-cycle strain-controlled fatigue at strain levels slightly above yield of the weld metal and twice the strain at yield. Care is also taken to perform the testing at credible field temperatures. Although weldments in pressure vessels or in the pipelines of current concern are not subjected to service stresses and strains of this magnitude, any flaw which can be shown to be innocuous under these severe conditions will have such a low probability of initiating flaws under essentially static conditions as to justify limiting their content on pragmatic reasons without incurring the. complexities of the analytical fracture mechanics approach.[3]

In the present work, a comparison is made between the number of cycles to crack initiation in pipeline girth welds made in AP5LX-65 line pipe by manual (SMA) cellulosic electrodes and by an automatic process. In addition to sound welds meeting the API 1104 workmanship criteria, very badly flawed welds were prepared containing porosity levels giving 15% radiographic obscuration, continuous slag and arc strikes imposed after the welding operation. Specimens containing a 4 inch length of weldment were fatigued in a transverse manner at strains slightly over yield (± 0.22%) and at twice yield (± 0.45%) while maintaining the temperature at -2 ± 1 °C. Crack initiation was monitored by observing changes in the load required to maintain the strain range. A 10% drop in load, representing development of a 10% cracked area, was taken as the criterion for crack initiation. Tests were continued until a 40% load drop (40% cracked area), was achieved so as to provide information on crack propagation. Specimens were then broken in tension for fractographic analysis.

The results obtained from 37 specimens representing parent metal as well as sound and flawed weldments, tested with the reinforcement cap both intact and machined off, appear in Figs. 1 and 2. From Fig. 1, it is seen that approximately 800 cyclic reversals were required for crack development when the weld cap was intact, regardless of whether the welds were sound or contained very large amounts of porosity, slag or arc strikes. Even for strain reversals equal to twice yield, about 30 cyclic reversals were required. Removing the weld cap forces failure through the flawed welds, decreasing the fatigue life to initiation: But even here, about 150 cyclic reversals were required at just over yield and about 25 at twice yield for crack initiation.

The data plotted on Fig. 2 relate more closely to field conditions, as the weld reinforcement cap is intact in all cases illustrated. This figure also examines the effect of specific flaw types. The performance of the unwelded, parent material is also illustrated.

The top plot illustrates that the automatic welds containing 15% porosity by projected area (about 3% by volume) performed equally well as did welds free of porosity or other flaws. The center plot illustrates that the presence of slag somewhat decreases the cyclic life to crack initiation; nevertheless, about 750 reversals were required at just above the yield and about 30 at twice yield to achieve initiation. The lower plot illustrates that arc strikes had no effect on cyclic life. In no case were weld failures observed to initiate from such flaws. Arc striking the parent plate was likewise ineffective in initiating fracture at the ± 0.22% strain level. It was necessary to strain the arc struck parent material at ± 0.45% before any effect was noted.

These data add credibility to the argument that blunt flaws have a very low probability of initiating failure in an operating pipeline, particularly when it considered that the permissible flaw level would be limited in practice to substantially less than in the test series and that line is unlikely to see more than one or two deformations to strains above yield and that these would not be accompanied by reversal. The strongest case can be made for automatic porosity and manual arc strikes. Slag presents a slightly more complex problem because fractographic evidence shows that failures with this type flaw were influenced by the development of hydrogen-assisted cracking originating either from the slag inclusions or from micropores within the weld metal. It therefore appears that, to the extent that slag contributes to crack initiation, it does so by providing a surface for hydrogen segregation rather than from the stress concentration due to slag shape.

Returning to the original questions, available data suggest that porosity in automatic welds and arc strikes in manual welds are not significant in weld metal having the toughness of that studied. The probability of failure from slag also appears remote; however, the associated hydrogen cracking arising from the use of cellulosic electrodes needs further analysis. These results suggest that it is probably unnecessary to dimension such flaws in order to establish a valid fitness-for-purpose criteria for their content in a weld. Finally, we conclude that radiography is effective in detecting the presence of such flaws, but is of very questionable effectiveness in the detecting or dimensioning of two-dimensional, planar flaws of the type that have a much higher probability of initiating weld failure. It remains for other NDE systems such as ultrasonics to perform that task.

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TABLE I

Sample Breakdown of Flaw Types Exceeding API 1104 Workmanship Standards in Pipeline Welding

	Number Observed	% of Total	
Planar Flaws			
Incomplete penetration	3	1.0 %	11.8 %
Incomplete fusion	21	7.3 %	
Cracks	10	3.5 %	
Blunt Flaws			
Porosity (gas pockets, hollow beed, scattered porosity)	57	20.0 %	88.2 %
Slag	6	2.0 %	
Arc strikes	190	66.2 %	
Total Flaws	287		
Total Welds	195		

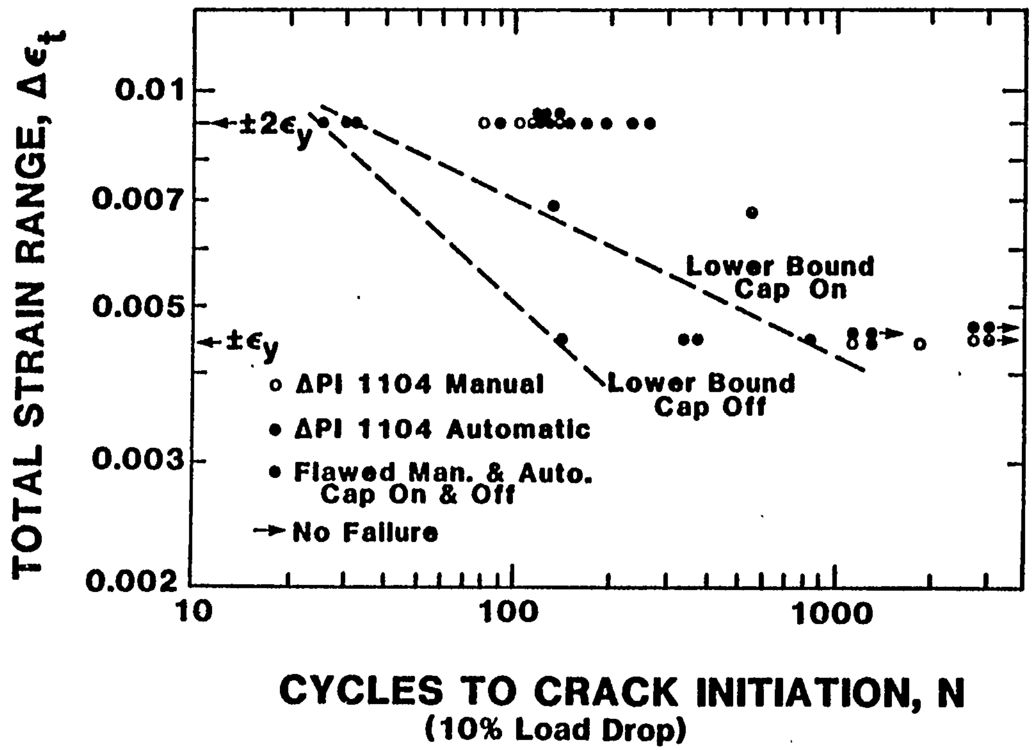

Fig. 1 Summary of the number of cyclic reversals to crack initiation as a function of strain range for sound pipeline girth welds and for welds containing porosity, slag and arc strikes tested in fully-reversed fatigue under strain control at $-2 \pm 1^{\circ}C$.

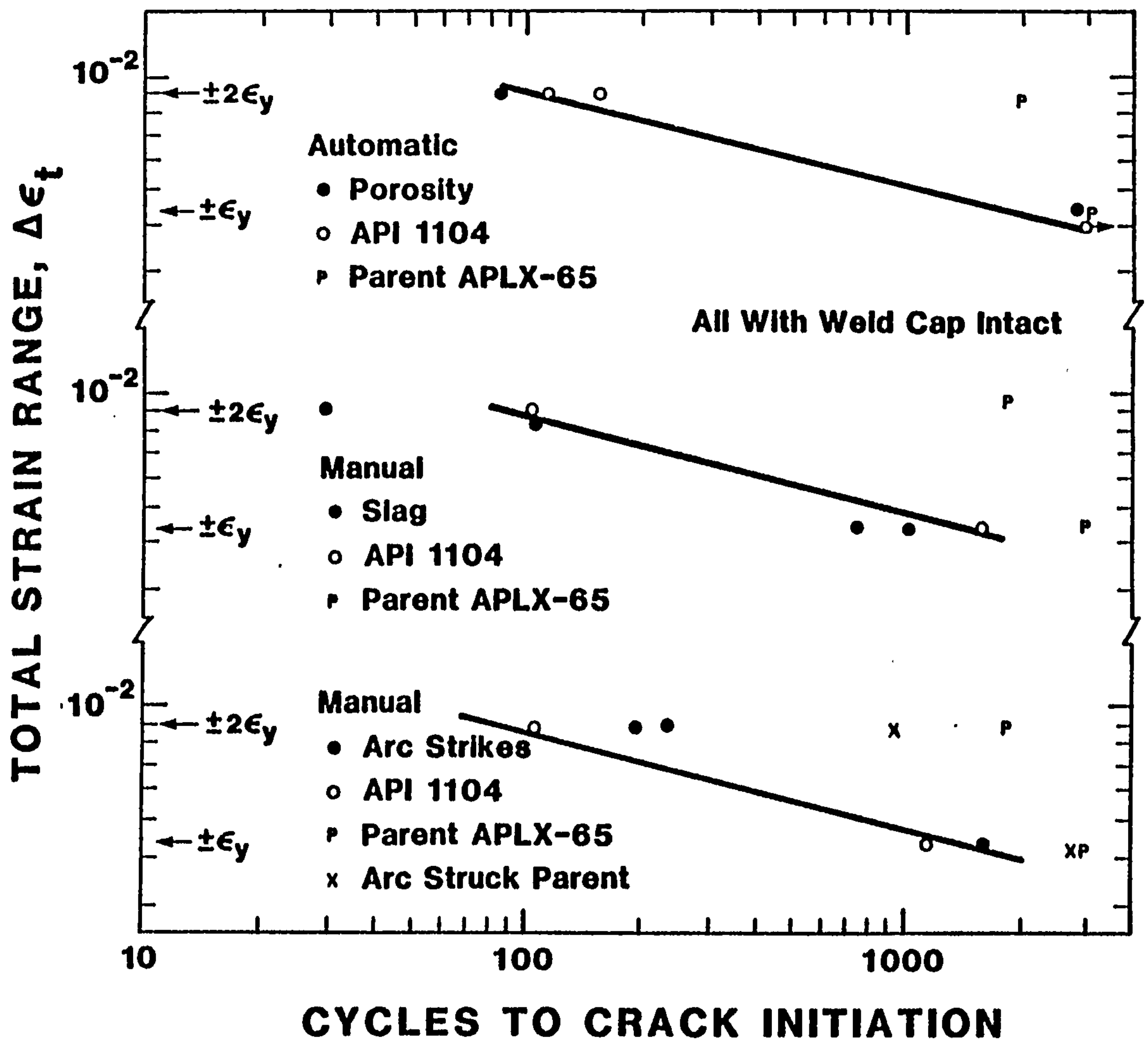

Fig. 2 Number of cyclic reversals to crack initiation as a function of strain range for weldments containing specific flaw types as compared to welds meeting the API 1104 workmanship code. Solid line defines the lower bound performance of sound welds.

Ultrasonic Detection and Sizing of Weld Defects

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Ultrasonic nondestructive evaluation (NDE) techniques are widely used in the detection of weld defects, because they are inherently more sensitive to two-dimensional weld defects such as incomplete fusion (IF) and cracks than conventional field radiographic techniques. Often the data obtained with ultrasonic NDE is examined further in order to determine the defect size information which is necessary in order to assess the fitness-for-service condition of a particular welded structure. One of the widely accepted methods for ultrasonic defect size determination is based on the scattered ultrasonic amplitude. The defect sizing is accomplished on the basis of comparative reference standards (calibration blocks) which are typically composed of sets of artificial defects of known dimensions and orientation. Examples of such artificial defect standards include: side-drilled and flat-bottomed holes to simulate internal defects and electron-discharge-machined (EDM) notches to simulate surface defects. Field calibration procedures are also provided in order to enable the operators to standardize instrument settings. However, the use of the comparative reference standards may not be adequate for accurate sizing of real defects. Briefly, the amplitude of the scattered ultrasonic signals can be strongly affected by the defect shape, type and orientation. In addition, the scattered ultrasonic amplitude depends strongly on the spectral distribution of the probing ultrasonic signal and on transducer response characteristics. Consequently, the amplitude of the scattered ultrasonic signals cannot be expected to increase monotonically with defect size, as predicted by the simple theory of geometric optics.

A number of unique approaches have been developed in order to overcome the fundamental problems associated with the overreliance on the scattered ultrasonic amplitude data for defect size determination. However, most of the new developments are based on rather subtle phenomena,[1] require skilled operators and are difficult to automate. Recently a new ultrasonic technique has been developed which may be particularly suitable for NDE of welded structures.[2,3]

The new ultrasonic technique is particularly suitable when the nondestructive examination of a welded joint must be performed at rapid rates and under adverse environmental conditions. The new technique differs substantially from conventional ultrasonic techniques in three respects: 1) the wavelength of the ultrasonic probing signal is long in comparison to the defect through-wall dimension, 2) the ultrasonic probing signals are polarized horizontally with respect to the surface of the weldment (SH-waves), and 3) non-contacting, electromagnetic-acoustic transducers (EMATs) are used to excite and detect the ultrasonic probing signals. Consequently, the new ultrasonic technique constitutes a new development in the field of ultrasonic detection and sizing of defects in welded joints.

The new ultrasonic technique is particularly useful for detection and sizing of elongated weld defects such as: incomplete fusion (IF), inadequate penetration (1P), elongated slag, and alignment mismatch.

Because the wavelength of the probing ultrasonic signals can be made longer than a typical defect through-wall dimension, the laws of simple geometric optics do not apply and the amplitude of the back-scattered ultrasonic signal can be expected to increase monotonically with defect size. In fact, for elongated defects the back-scattered ultrasonic amplitude can be expected to be directly proportional to the defect length and to the square of the defect through-wall dimension. The non-linear dependence of the ultrasonic amplitude on the defect through-wall dimension is a useful property, because it reemphasizes the detection of-small defects, thereby reducing the false alarm rate. In addition, because the wavelength of the probing ultrasonic signals is long in comparison to the defect dimensions, the scattered ultrasonic amplitude is relatively insensitive to minor perturbations in defect shape and orientation.

Another important advantage of the new ultrasonic technique is associated with the use of horizontally-polarized ultrasonic probing signals (shear-horizontal or SH waves). In conventional ultrasonic testing, fluid coupled transducers excite and detect ultrasonic probing signals which are polarized in the plane normal to the surface of the weldment (saggital plane). At the fluid-solid interface, the transducer signals can be split up into two kinds of shear (SH and SV), longitudinal (L), and Rayleigh (surface) waves which travel in different directions at different velocities. This situation can lead to considerable ambiguities in signal interpretation which can complicate the task of automating the nondestructive evaluation process. However, in contrast to the conventional (piezoelectric) ultrasonic transducers, the SH-wave transducers are sensitive to only one kind of ultrasonic signal,the SH-wave, and effectively discriminate against SV-wave, L-wave and Rayleigh wave signals which can contaminate the ultrasonic displays. This property of the SH-wave transducers results in a significant reduction in complexity of the ultrasonic displays. In addition, SH-waves are not scattered strongly by the weld reinforcement (crown). As a consequence, SH-wave inspection systems should be easier to automate and require less operator skill.

Because SH-wave transducers are noncontacting EMATs, inspections can be carried out over most unprepared and painted surfaces. Inspections at elevated and low temperatures, and under water may also be in prospect.

In-summary, a new ultrasonics NDE technique has been developed. The technique is particularly useful for detecting elongated weld defects such as incomplete fusion, inadequate penetration, elongated slag and alignment mismatch. In addition, the technique is not sensitive to the presence of weld reinforcement which often reduces the sensitivity of conventional ultrasonic and field-radiographic techniques. Because the wavelength of the probing ultrasonic signals is long compared to the defect dimensions, the scattered ultrasonic amplitude varies monotonically with defect dimensions and is relatively insensitive to minor perturbation in defect shape and orientation. As a consequence, the ultrasonic amplitude can be used reliably for defect sizing. Although the new ultrasonic NDE technique cannot precisely locate the position of a defect inside a weldment, it can be supplemented by higher resolution techniques such as short-wavelength-ultrasonic probing and field-radiographic examination. Finally, the new ultrasonic NDE technique requires less operator skill and is easier to automate than conventional ultrasonic techniques.

References:

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Acceptance of Standards -
The Coast Guard Approach

The Coast Guard's approach, as a regulatory body, to the acceptance of industry 0r classification society standards with respect to mild steel hull welding is relatively straightforward. Title 46 of the Code of Federal Regulations (46 CFR) subparts 31.10-1 and 92.01-10 require compliance with the standards" established by the American Bureau of Shipping (ABS) for satisfactory evidence of the structural efficiency of a vessel. In addition to designating the ABS standard as the Coast Guard standard, Coast Guard regulations also provide that the current ABS standard in effect at the time of construction of a vessel. shall be used. Any supplementary Coast Guard requirments imposed because of special considerations such *as* the *use* of higher strength steels, are publicized through regulations addressing the particular application.

There are some factors which confuse this otherwise straight forward arrangement. One is the tendancy to confuse the Coast Guard requirements for mild steel hull welding with the Coast Guard requirements for pressure vessel. and piping welding. Another source of confusion is owner imposed requirements Which mistakenly become identified with Coast Guard requirements. In general, however, the Coast Guard approach to accepting standards, at least in the area of hull stucture, is a direct recognition of the ABS standards through appropriate regulations which directly reference the ABS standards.

E. J. Holler
Mechanical Engineer
U. S. Coast Guard

III

GENERAL SESSION

2nd Day of the Conference

OPENING REMARKS

by

LES SANDOR

Manager, National Shipbuilding Research Program

(Moderator, 2nd day of conference)

GOOD MORNING!

Yesterday's session was INFORMATIVE. That was the easy part!

This conference was not conceived to generate new weld acceptance standards, rather to come up with an AGREEMENT on how to go about optimizing weld acceptance standards in the light of the contents of the "WELD DEFECT TOLERANCE STUDY" report.

During the intermissions yesterday, I went from group to group as you were talking and tried to listen to as many of you as I could. More importantly, last night in the "social hour" I was particularly and keenly interested in hearing your comments.

Why?

There is an expression in Latin: "IN VINO VERITAS".

In English it means, "THE TRUTH IS IN WINE".

Some of you know that my "roots" go back to Hungary. Over there, they teach Latin in school. This expression is all that I know and remember about those Latin class room sessions. Maybe, in this country we ought to change that expression to say,

"THE TRUTH IS IN WHISKEY"

Of your many comments, one was most challenging to me. It compelled me to change my original speech. So, I am going to digress and philosophize. The comment was, "Should we really change anything?"

FIRST, maybe we should ask this fundamental question: How and why did we come to Boulder?

SECOND, How did we manage to bring about the 1981 international conference on “Fitness-for-Purpose Validation of Welded Constructions”, London, England. Who are its sponsors. Why are we planning to hold a similar, follow-on international conference in the U. S. in 1982.

THIRD, why is there still a strong demand for additional copies of the “Weld Defect Tolerance Study” report. (So far 250 copies were distributed and 200 more are in print now.)

I’d like to think that we travelled to Boulder not for socializing, but because we felt that there was indeed a genuine need to minimize the cost of welding through reducing unnecessary weld repair.

Much has been written about the significance of weld discontinuities in the world. In our study, we tried to put things in perspective for the U. S. shipbuilding industry. What is now required is for all of us to find the mechanism by which to bring to fruition all that we know TODAY about weld defects in shipbuilding from the point of view of FITNESS-FOR-SERVICE.

The importance of fracture mechanics as an engineering tool to assess whether a defect is harmful or not is underscored by the up and coming international conferences on fitness-for-service/purpose. The sponsors of these conferences include such prominent institutions as The Welding Institute, The Welding Research Council, the American Welding Society, the National Bureau of Standards (Boulder).

There are good reasons for SP-7 Panel to support projects which will lead to optimizing existing workmanship-type standards.

The “Quality Control Systems Loop” is excellent for establishing cause-and-effect relationships. Whether QCSL is confined to activities within the shipyard or is expanded to include the in-service performance of the ship as well, depends on short-or long-term objectives to be achieved by its user.

The fact that issues of the “Weld Defect Tolerance Study” are still requested nationally and internationally is interpreted to mean something good for its seeker.

You are the force, which turns the wheels and starts the engines” of your industry. What is needed is a commitment from that force.

I ask,

Do you want to be the guardian of the status quo?

You have to answer that question yourselves!

I ask,

Do you think that there is no room for improvement?

In this connection, I find it proper to pose an extremely important question:

WHAT IS LEADERSHIP?

I give you my definition:

- o Remembering the past,
- o Recognizing the present,
- o Reaching out to seek and test the unknown.

If it is not the embodiment of all these three things, I am afraid, the leadership is not good enough!

I am now reminded of my years in Europe that the world would look up to America to emulate and hold on a pedestal.

I ask,

Do you want to come down from that pedestal?

May I hope that your answer is a resounding NO!

We are not so naive to tell you that all that is needed for improving the present, but not so rosy situation of the U. S. shipbuilding industry is to merely **come** up with new weld acceptance standards. In my presentation yesterday, I was speaking about such matters as design details

technology to improve fit up

QCSL

– total participation--to get the workers involved in the system of quality, decision making, re-education, etc.

Weld acceptance standards are, however, a vital part of that total picture. How and by what means we want to judge either the acceptance or the rejection of welds is up to us. Let us make that decision in a team spirit: IN THE SPIRIT OF BOULDER, I might add.

With that, I now declare this session of the conference an

OPEN FORUM.

Conference on "Fitness-for-service in Shipbuilding"

National Bureau of Standards
Boulder, CO 80303

October 23-24, 1980

Contributions to the general discussions by M. G. Dawes, The Welding Institute/NBS

I would like to-make the following points regarding the application of fracture mechanics to the fabrication and operation of welded structures such as ships:

1. Around the world there is an increasing emphasis on product liability. This is due to the increasing public concern over the loss of life, capital equipment and damage to the environment resulting from service failures.
2. As far as the general public is concerned, no structure should contain defects.
3. In fact, all engineering materials and structures contain defects at some scale of examination.
4. If we argue.that present quality control methods allow some defects to be accepted, based on operating experience, we will not convince the public. This will be especially true when we extrapolate our experience to new designs and new materials.
5. Therefore it seems inevitable, at some stage, that the customers, operators, and insurance companies, and ultimately the fabricators, will be forced to use fracture mechanics with increasing frequency in order to quantify and prove the significance of defects.
6. It would be naive, however, to suppose that we could apply fracture mechanics approaches overnight.
7. Obviously, fracture mechanics must be introduced gradually along with a continuation of present quality control methods.
8. Ultimately we will achieve a balance between the application of quality control and fracture mechanics methods.
9. It is important to start looking at what fracture mechanics has to offer now; I believe that to put it off, is to put off the inevitable!
10. The ship fabricators, owners and operators are not unique in facing-up to these problems. In fact, all engineering industries are involved in applying or assessing fracture mechanics to varying extents at this time.

IV

CONCLUSIONS AND RECOMMENDATIONS

SUBJECT: Boulder Conference: "Fitness-for-Service in Shipbuilding"

ATTENTION: Messrs. J. Fallick and J. Mason
Chairmen of SP-7 and SP-6, respectively

DATE: October 29, 1980

I have two reasons for writing this memorandum on the subject matter.

1. To inform both of you about the outcome of the conference

2. To give you my personal views as a result of point No. 1

Since both of you are fully cognizant of the entire history and the conclusions as well as the recommendations contained in the final report on Weld Defect Tolerance Study, Phase I, I shall not bother with its details.

(1) BOULDER CONFERENCE OUTCOME

1.1 Traditional Approach:

The ABS representative and the SP-7 Panel chairman were more inclined to pursue now the optimization of existing weld acceptance standards under purview of two workmanship-type projects already approved by SP-7 for ABS. They offered, among others, as a reason for that inclination shorter term objectives than they felt might be possible with analytical fracture mechanics. Neither of them, however, ruled out the usefulness of the fracture mechanics approach. They indicated that fracture mechanics, because of its newness, implies longer term benefits to current needs of - at least - some shipyards.

1.2 New Approach:

After a due debate, the delegates, by a show of hands, unanimously voted and agreed to continue with Weld Defect Tolerance. It was then a question of how, and to whom the task of continuation ought to be presented.

In the Policy Planning Session, a proposition from the floor was taken up and agreed upon. The motion was to take a vote on three (3) options for recommending actions with respect to fracture mechanics-based weld acceptance standards to the Ship Production Committee Panels of SP-7 and/or SP-6. The outcome of the vote taken by the delegates - then present - is tabulated below.

No.	Options	Number of Votes
1	Drop	0
2	Guide	23
3	Standard	1

I shall not bias the results of the voting by my editorializing. They speak for themselves.

It may be useful to give the definitions of the three options:

Option 1: Drop - No further work on weld defect tolerance

Option 2: Guide - Offer fracture mechanics-based data as a guide for resolving special cases (i.e., a tool of "arbitration" or option indeed)

Option 3: Standard - Replace now the existing workmanship - based standards with fitness-for-service weld acceptance standards.

1.3 QCSL

During the conference, the Quality Control Systems Loop was discussed. One of the basic premises of QCSL is the establishment of cause-and-effect relationships in terms of both short range and long range objectives.

For example, a relationship can be established between an agreed number of different results, obtained in a yard and the performance of those different results determined by re-inspection after a specified length in service of the ship(s).

Mr. A. M. Morrow, Assistant Director of QA, Tacoma Boat, expressed a strong desire to introduce the Quality Control Systems Loop concept in his shipyard and test it out on two ships of new construction. He asked for a copy of the final report on Weld Defect Tolerance so as to get acquainted with the details of QCSL.

(2) PERSONAL VIEWS

I support all three approaches towards optimizing existing weld acceptance standards. 1 do not take this "middle of the road" attitude merely to be a project managerial "politician". This attitude comes from my engineering'convictions rooted in a bona fide recognition of the present state of the shipbuilding industry, which consists of the following facts - at least as i knew them to be.

Be it the traditional - or the fracture mechanics - or the QCSL approach, the three do indeed compliment one another in more ways than one. To name a few, let me say that each approach:

- stands for quality improvement at the lowest possible cost, which I am sure, we all applaud,
- offers some things positive and some that are negative, which, neither on its own merits alone can resolve without resorting to "a guessed margin of safety". The combination of the three approaches will minimize "the guess work", which - again - we all desire,
- takes time to reduce to the level of "waterfront activities",
- requires in service verification to attain the kind of confidence level, which such large investments as ships together with human lives and cargo - used in an illusive environment demand from us in terms of safety and servivability.

This three-pronged approach requires coordination - for reasons of efficiency, if nothing else. One of the more fundamental questions, which enters one's mind and cries out for resolution is who should sponsor what and how. A second question that may be posed, is there a need to form a task force on any of these approaches. I am inclined to propose that for the two SP-7 projects subcontracted to ABS, SP-7 as a committee or its National Shipbuilding Research Program manager should suffice. For the fitness-for-service approach, a special task force might be useful to legislate under either SP-7 or SP-6. In this. connection, it might be appropriate to mention the U.S. Coast Guard's suggestion to this writer during a telephone conversation for considering the Ship Structure Committee as a viable alternative. According to the Coast Guard, SSC, is in sympathy with the Weld Defect Tolerance Study.

As for the QCSL avenue, I am tempted to suggest that all is needed is a shipyard or two to implement it as per their own specific requisites.

The results and the general information from each of the three approaches should flow into a central location. The Center should analyze the data and inform/advise every important sector of the shipbuilding community: shipyards, regulatory bodies, owner/operators, design offices and manufacturers of materials as well as consumables. Comments and feedback to the Center should also be solicited.

In sensing the spirit of cooperation, may I ask both of you to reflect on the contents of this memo. I am not known to have ever refused to help out in a common cause for the better for all of us in the U.S. Shipbuilding Industry.

I trust I shall hear from you.

Yours truly,

Les

L. W. Sandor
Manager, NSRP

cc: E. Peterson R. Schaffran
J. Garvey

SUN SHIP, INC.
INTER-OFFICE CORRESPONDENCE SHEET

SUBJECT SP-7 Newsletter **DATE** October 27, 1980 (PE/37/JF)

FROM J. Fallick

TO L. Sandor

I would like to send out a newsletter to SP-7 as an editorial from me to reflect my opinions of the Defect Tolerance Program at Boulder. I would like the editorial to read as follows:

> The Defect Tolerance Program held at Boulder, October 23-24, 1980 re-surfaced many of the original problems in the application of fracture mechanics to establishing clear guidelines for Weld Acceptance Criteria Standards.
>
> We, as a committee, originally rejected our involvement in fracture mechanics from the point of view that it was too long ranged a program for our involvement. The Ship Production Panel SP-6 Standards picked up on this issue in the Defect Tolerance Study recently issued by L. Sandor. The summation of that report, in actuality, says no more than many other reports previously issued which made the same conclusion. The Boulder conference was, in fact, much of the same. With respect to future work in this area, I would like to recommend to the Panel the following:
>
> 1. That we continue our work with ABS in more clearly defining Visual Acceptance Criteria and what would be acceptable inspection criteria for non-critical ship locations, if required by owner-yard specification.
>
> 2. Leave fracture mechanic details to the experts in fracture mechanics and urge the regulatory bodies to keep abreast of technology changes in this area so that at some future date, when the technology is available, or as required by special situations, that they avail themselves of it as applicable.

Your comments on these recommendaitons are solicited.

Jon Fallick

JF:bd

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700 WASHINGTON STREET, BATH, MAINE 04530

Nov. 5, 1980

Dr. L. W. Sandor
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Subj: Weld Defect Acceptance Standards

Ref: (a) Your memo on the Boulder Conference: "Fitness for Service in Shipbuilding," dtd. Oct. 29, 1980

Dear Les:

Reference (a) has provided a good summary of the results of the Boulder Conference and where we now stand relative to the development of new\revised weld defect acceptance standards to reduce shipbuilding cost\time. The purpose of this letter is to offer my recommendations for follow-on action to ensure optimum, implementable results - both near and long term.

To be concise, the following key points represent my thoughts on the subject:

(1) The two short-term projects already approved by SP-7 for accomplishment by ABS should clearly move ahead on an independent basis to provide the expected near-term benefits to the industry. It must be recognized that transition to the use of fracture mechanics based standards will\must take time and will continue to be balanced with workmanship-based standards.

(2) The potential benefits of reduced weld repair through application of fracture mechanics based standards for slag inclusions and porosity warrants immediate follow-on action in this area. It is recommended that a task group be organized under the umbrella of the ASTM Shipbuilding Welding subcommittee, F-25.12, with the objective of developing consensus guidelines for repair relative to slag and\or porosity defect conditions. The ASTM mechanism facilitates all segments of the industry meeting under neutral and balanced conditions; and because of the due process system, obviates potential legal problems (antitrust, liability, etc.). It should be noted that (1) the May 19, 1980 shipyard workshop sponsored by ASTM F-25 identified weld acceptance standards as the highest priority area for F-25.12, and (2) the

V.

CONFERENCE ATTENDEES

SHIP ARC

Edited by SNAME Founded in 1980 SP-7 PANEL

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Boulder, Colorado
National Bureau of Standards

FIRST CONFERENCE ON FITNESS-FOR-SERVICE IN SHIPBUILDING

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